

Groundwater Fluoride in Haryana State: A Review on the Status and Its Mitigation

Ruchi Gupta¹, Anil Kumar Misra²

¹The Energy and Resources Institute (TERI), India Habitat Centre, Lodhi Road, New Delhi, India

²Department of Civil and Environmental Engineering, ITM University, Gurgaon, Haryana, India

*¹ruchig@teri.res.in; ²anil_kumar_misra@rediffmail.com

Received 23 April 2014; Accepted 22 May 2014; Published 26 June 2014

© 2014 Science and Engineering Publishing Company

Abstract

Approximately 75% to 80% population in Haryana state uses groundwater for domestic, irrigational and industrial purposes. Due to high concentration of fluoride, in groundwater, dental fluorosis has become a common disease in the state and symptoms of skeletal fluorosis are prominent among adults in different districts of Haryana state. In districts like Sonapat, Faridabad, Bhiwani, Panipat etc. the fluoride ion concentration in the groundwater has reached more than 6mg/L and majority of the part of the districts show groundwater fluoride concentration more than permissible limit (1.5 mg/L). In some districts such as Jind, Sonapat, Faridabad, Sirsa Hisar, the fluoride is present at few sites but the range is more than 3 mg/L and some other districts such as Ambala and Yamunanagar are safe from problem of fluorosis. This paper presents an assessment on presence of fluoride ion for all districts of Haryana and proposes suitable management strategies and insitu and exsitu mitigation treatment methods to manage the further deterioration of groundwater quality.

Keywords

Groundwater; Fluoride; Haryana; Dental Fluorosis; Defluoridation

Introduction

Groundwater is the major source of drinking water in India. More than 85 percent of India's rural domestic water requirements, 50 percent of its urban water requirements and more than 50 percent of its irrigation requirements have dependence on ground water resources (Jha, 2008). The combined impact of increasing dependence on groundwater and depleting water table, the contaminants level rapidly increases in

the groundwater. Groundwater composition in a region depends on the natural such as the wet and dry deposition of atmospheric salts, evapo-transpiration, soil/rock water interactions and that of the anthropogenic process which can alter or modify the natural system of hydrological cycle (Singh et al., 2006, Kumar, 2011). Fluorine is one such element existing naturally in water in form of fluoride. The weathering of primary rocks and leaching of fluoride containing minerals in soil yield fluoride rich groundwater in India which is generally associated with low calcium content and high bicarbonate ions (Daniel and Karuppasamy, 2012) and prolonged intake of such groundwater causes health problems. High concentration of fluoride in the groundwater of different parts of the world is responsible for widespread Fluorosis. In India, 19 states have been identified having fluoride concentration in groundwater more than the permissible limit. Haryana is one of the states where problem of fluorosis is widespread. 14 districts in Haryana viz. Bhiwani, Faridabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Kurushetra, Mahendragarh, Panipat, Rewari, Rohtak, Sirsa, Sonapat have fluoride concentration more than 1.5 mg/litre permissible limit prescribed by Bureau of Indian Standards (BIS) in groundwater wells (CGWB, 2010). Previous studies were carried in many districts of Haryana to investigate fluoride concentration in groundwater (Singh and Garg) that includes Panipat (Bishnoi and Malik 2008), Hisar (Khailwal and Garg 2006, 2007), Jind region (Mor et al. 2003; Meenakshi et al. 2004), Bhiwani region (Garg et al. 2008) and Gurgaon region (Singh et al. 2007). Singh et al. (2007) has reported the fluoride content in the groundwater of Pataudi block of Gurgaon district in the range of 0.95 and 5.20 mg/l. Garg et al. (2008)

reported up to 86.0 mg/l fluoride content in the groundwater of rural habitations of Bhiwani district i.e. highest fluoride content ever recorded for Haryana state including India. Meenakshi et al. (2004) conducted study in 4 villages of Jind district of Haryana state showing that fluoride concentration in 4 villages of the district was in the range of 0.3 to 6.9mg/l, causing dental fluorosis among people especially children of these villages. Another study carried out by Bishnoi and Arora (2007) in ten villages of Rohtak district of Haryana state showed fluoride concentration which varied from 0.034 – 2.09 mg/L. Though several studies have been conducted in past on assessment of fluoride content in groundwater in Haryana but there was no single study that presented the fluoride data for all districts of Haryana. Further, the data compared for all districts were taken from central ground water board for three years. The objective of this study was to investigate the present status of fluoride concentration of groundwater in districts of Haryana state and formulated suitable management programme for defluoridation.

Description of the Study Area

Haryana is located in the northwest direction of India having an area of 44,212 sq kms. It lies between 27.37° N and 35.30° N latitude and 74.28° E and 77.36° E longitude. The state is surrounded by 6 states. Punjab is in the northwest, Himachal Pradesh and Uttarakhand in the north and northeast, Delhi and Uttar Pradesh in the east and southeast and by Rajasthan in the west and southwest as shown in Fig. 1.



FIG. 1 LOCATION OF HARYANA IN INDIA

Monitoring Studies

The Monitoring of ground water is an effort to obtain information on ground water levels and chemical quality through representative sampling. The Central Ground Water Board (CGWB) performs monitoring of groundwater quality of all states of India through the observation wells.

As on March 2012, a network of 15653 observation wells located all over the country that is being monitored by CGWB. Ground water samples are collected from these observation wells to obtain background information of ground water quality changes on regional scale. In Haryana, about 464 observation wells are present. Assessment of Fluorosis prevalence in groundwater is carried out based on the criteria provided by World Health organization (WHO). Table 1 shows the effects of fluoride on human health. The data from CGWB website (<http://gis2.nic.in/cgwb/Gemsdata.aspx>) is extracted for the year 2007 to 2009 to assess the concentration of fluoride ion in groundwater of Haryana State.

TABLE 1 EFFECTS OF FLUORIDE ON HUMAN HEALTH

S.No.	Fluoride concentration	Effects
1	Nil	Limited growth and fertility
2	< 0.5	Dental caries
3	0.5 -1.5	Promote dental health and prevent tooth decay
4	1.5 – 4.0	Dental fluorosis (mottling and pitting of teeth)
5	4.0 – 10.00	Skeletal Fluorosis
6	> 10.00	Crippling Fluorosis



Current Status

Current studies indicate that majority of the districts of Haryana have fluoride in groundwater more than permissible limit i.e., 1.5 mg/L. However, occurrence of fluoride more than 3 mg/L which can be the cause of skeletal Fluorosis is limited to some sites as shown in Table 2. Table 2 provides the assessment of fluoride concentration in groundwater for the Haryana State.

TABLE 2 PRESENCE OF FLUORIDE ION IN GROUNDWATER IN HARYANA (CGWB, 2010).

District	No. of sites Investigated in all three years (2007 to 2009)	Occurrence of Fluoride ion		
		More than 1.5 mg/L**	More than 3 mg/L	More than 6 mg/L and above
Sirsa	33	10	4	1
Rohtak	4	2	-	-
Rewari	20	4	2	-
Panipat	33	15	3	-
Panchkula	16	1	-	-
Mahendragarh	6	2	1	-
Kurukshetra	10	1	-	-
Ambala	30	-	-	-
Bhiwani	35	14	4	1
Faridabad	35	16	7	2
Fatehabad	22	6	2	2
Gurgaon	42	1	-	-
Hisar	42	11	5	-
Jhajjar	32	5	3	-
Jind	34	10	3	2
Kaithal	33	9	-	-
Karnal	49	8	1	-
Sonepat	48	20	7	3
Yamunanagar	39	-	-	-

The districts of Haryana such as Faridabad, Sonapat, Panipat, Bhiwani etc have samples that have high values of fluoride ion. In these districts, 30 to 40% of the investigated sites are having fluoride ion more than permissible limit which is not safe more human health. In these districts, some of the sites have fluoride even more than 3 mg/L in groundwater which indicates dental fluorosis. Faridabad, Fatehabad and Sonapat districts have serious concern for fluorosis as there are few sites having fluoride ion more than 6mg/L, which may cause skeletal fluorosis.

Mitigation and Management Strategies:

Mitigation and management of groundwater quality are imperatively needed in Haryana state in order to prevent the further deterioration of groundwater quality. Since no other source of water is available for supply therefore for long lasting solution Insitu and exsitu methods (Brindha and Elango, 2011) can play

an important role in defluoridation of groundwater.

Insitu-treatment Methods

This method involves directly diluting the concentration of fluoride in groundwater through artificial recharge structures or rainwater harvesting. Studies show that the construction of check dams in Anantapur district, India has helped widely to reduce fluoride concentration in groundwater (Bhagavan and Raghu, 2005).

Exsitu-treatment Methods

This method involves defluoridation of groundwater using household filters and water treatment facilities at district level. Studies carried out on adsorption method shows that the passage of water through a contact bed where fluoride is adsorbed on the matrix. Several workers have used activated charcoal and activated alumina as adsorbents (Chidambaram et al., 2003; Chauhan et al., 2007). Brick, bone char, fly ash, serpentine, red mud, waste mud, rice husk, kaolinite, bentonite, charfines, ceramic etc. are some of the other adsorbents capable of effectively removing fluoride from groundwater (Srimurali et al., 1998). Nalgonda technique which is a wellknown technique uses alum, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation and filtration. This is developed in India by National Environmental Engineering Research Institute to serve at community and household levels.

Apart from removal techniques, affect of excess intake of fluoride can be reduced by good diet and nutrition which can control the damaging effect of fluorosis. The deficiency of Calcium and vitamin C is recognized as important exacerbating factors. Therefore the diet rich in calcium and vitamin C needs to be supplemented in fluoride endemic habitations. Thus the best method of mitigating fluorosis is to implement defluoridation techniques in the affected areas and change dietary habits of vulnerable people from the lower income group.

Results and Discussions

Groundwater fluoride above the permissible limit that is >1.5 mg/l in drinking water, (BIS, 1991) has become an endemic in 17 States of India. Occurrence and distribution of fluoride are not uniform in Haryana state; it drastically varies in different districts. In Haryana, fluorosis appears in three forms that are, skeletal fluorosis, dental fluorosis and non-skeletal

(soft-tissue) fluorosis, of which the former two types are irreversible. Majority of the rural populations in state is dependent on groundwater for potable water supply that contain fluoride above the permissible limits of 1.5 mg/l is escalating fluorosis problem in the state.

CGWB data show that the fluoride concentration varies in different districts of Haryana, even variation occurs at different sites within the districts. One of the reasons may be electronegative behaviour of the fluorine. The type and extent of chemical concentration of the groundwater are largely dependent on the geochemistry of the soil through which water flows prior to reaching the aquifers (Kumar, 2011). The geology of Haryana is predominated by the Quaternary alluvium and aeolian sediments covering nearly 95% of area. The rest of the area comprises Proterozoic and Tertiary rocks exposed in the southern and northeastern extremities of the state, respectively. The different geomorphic units recognized include 1) High structural hills, 2) Moderate structural cum denudational hills, 3) Low structural cum denudation hills, 4) Older and younger piedmont zones, 5) Flood plain, 6) Older alluvial surface, 7) Aeolian zone, 8) Transitional zone and 9) Upland tract (Chopra, 1990). The soil of Haryana is mainly composed of brick earth, saltpeter and quartzite. Minerals like slate, badar sand are found in huge quantities in the Aravallis. Inexhaustible deposits of quartzite are found in the Aravalli ranges covering the districts of Faridabad, Gurgaon, Rewari. Low-grade haematite and jasperoid haematite occur in Ferozpur-Jhirka area of Gurgaon district. A number of major minerals, though in minor quantities, are also found in the state. These include arsenopyrite (Alwar quartzites in Gurgaon dist.) china clay (in the feldspathic pegmatite veins in Alwar quartzites in Faridabad and Gurgaon district), feldspars (in pegmatites intruding quartzites in Gurgaon dist.), garnet (in garnetiferous mica schist associated with Alwar quartzite in Gurgaon Dist.), graphite (in graphite mica schist occurring in Gurgaon dist.), foundry sand (in abandoned course of Yamuna river in Sonapat dist.), quartz (as intrusive veins with pegmatites in Gurgaon & Faridabad dist.). Studies show that during weathering of rocks, in humid and semi-arid climatic conditions, the geochemical fate of fluorine is controlled by a series of intricate adsorption-desorption and dissolution-precipitation processes (Deshmukh et al. 1995). Thus the existence of fluoride bearing rock material in most of the

districts of Haryana may be one of the reasons of continuous escalation in groundwater fluoride. Some cases of skeletal Fluorosis were also studied in the past, but it is not widespread as that of dental fluorosis. The problem of dental and skeletal fluorosis in Haryana state can be managed by implementing insitu and exsitu treatment methods.

Conclusions

Fluoride in groundwater mostly occurs because of the geomorphology of the aquifer below the groundwater. Most of the districts of Haryana have rock bed of quartzites, mica and clay, which is the preliminary case of fluoride existence in groundwater. Besides, it is also observed that at some sites, fluoride concentration varies from one to other. This may be due to the fluctuations in water table at those sites. Therefore, for understanding the cycle of fluoride concentration in groundwater, it is imperative to analyse the aquifer characteristics in detail. Further to reduce the impact of fluoride concentration at specific sites particularly in districts of Sonapat, Fatehabad and Faridabad, site – specific defluoridation techniques can be adopted.

The study demonstrates the followings:

- (a) The main source of fluoride in groundwater in Haryana state is the availability of fluorine rich geological formation and the weathering and erosion of these geological formations are continuously escalating the groundwater fluoride concentration.
- (b) The intake of fluoride above the permissible limit in drinking water is the major reason for both dental and skeletal fluorosis diseases in the Haryana state.
- (c) Implementation of both Insitu and exsitu treatment methods on large scale in all fluoride effected districts of Haryana is essential to manage the further deterioration of groundwater quality.

ACKNOWLEDGMENT

We thank all the faculty members of the Civil and Environmental Engineering Department of ITM University and Energy, Environment and Technology Development Division of TERI for providing working facilities and also for the encouragement of this work.

REFERENCES

- Bhagavan, S. V. B. K. and Raghu, V. "Utility of check dams in dilution of fluoride concentration in ground water and the resultant analysis of blood serum and urine

- of villagers, Anantapur District, Andhra Pradesh, India." *Environmental Geochemistry and Health*, 27 (2005): 97-108.
- Bishnoi, M. and Malik, R. "Ground water quality in environmentally degraded localities of Panipat city." *India J. Environ. Biol.*, 29(2009): 881-886.
- Brindhya, K. and Elango, L. "Fluoride in Groundwater: Causes, Implications and Mitigation Measures." In: Monroy, S.D. (Ed.), *Fluoride Properties, Applications and Environmental Management*, (2011): 111-136.
- Bureau of Indian Standards: Drinking water specification (First Revision), IS 10500 (1991).
- CGWB: Ground water quality in shallow aquifers of India, (2010).
- Chauhan, V. S., Dwivedi, P. K. and Iyengar, L. "Investigations on activated alumina based domestic defluoridation units." *Journal of Hazardous Materials*, B139 (2007): 103-107.
- Chidambaram, S., Ramanathan, A. L. and Vasudevan, S. "Fluoride removal studies in water using natural materials." *Water SA*, 29(3) (2003): 339-344.
- Chopra, S. "A geological cum geomorphological framework of haryana and adjoining areas for landuse appraisal using landsat imagery". *Journal of the Indian Society of Remote Sensing*, 18 (1990): 15-22.
- Daniel, J. and Karuppasamy, S. "Evaluation of Fluoride Contamination in Groundwater Using Remote Sensing and GIS Techniques in Virudhunagar District." *International Journal of Advanced Remote Sensing and GIS*, 1 (2008): 12-19.
- Deshmukh, A. N., Wadaskar, P. M. and Malpe, D. B. "Fluoride in Environment: a review." *Gondwana Geol. Mag*, 9 (1995): 1-20.
- Jha, B. M. "Towards Better Management of Ground Water Resources in India." *Central Ground Water Board*, New Delhi.
- Kumar K. K. "Geomorphological impact assessment on groundwater quality and fluoride genesis along the bay of bengal of visakhapatnam district, Andhra Pradesh, India". *Clean – Soil, Air, Water*, 39 (2011): 925-930.
- Meenakshi, Garg, V. K., Kavita, Renuka, Malik, A. "Groundwater quality in some villages of Haryana, India: focus on fluoride and fluorosis." *J Hazard Mater* 106B (2004): 85-97.
- Singh, B. and Garg, V. K. "Fluoride Quantification in Groundwater of Rural Habitations of Faridabad, Haryana, India" *International Journal of Environmental Protection*, 2(2012): 8-17.
- Singh, K. P., Malik, M., Mohan, D., Singh, K. V., Singh S. "Evaluation of Groundwater Quality in Northern Indo-Gangetic Alluvium Region," *Environ. Monit. Assess* 112 (2006): 211-230.
- Srimurali, M., Pragathi, A. and Karthikeyan, J. "A study on removal of fluorides from drinking water by adsorption onto low-cost materials." *Environmental Pollution*, 99 (1998): 285-289.
- WHO: International standards for drinking water, 3rd Edn., WHO, Geneva, (1971).

Ms. Ruchi Gupta, Research Scholar Department of Civil and Environmental Engineering, ITM University, Gurgaon, India

Dr. Anil Kumar Misra, Assistant Professor, Department of Civil and Environmental Engineering, ITM University, Gurgaon, India